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DRAWINGS ATTACHED

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(54) INDUCTION SYSTEM FOR MOTOR VEHICLES

(71) We, NISSAN MOTOR COMPANY, LIMITED, a corporation organized under the laws of Japan, of No. 2, Takara-machi, Kanagawa-ku, Yokohama City, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an induction system for a motor vehicle internal combustion engine and, more particularly, to an induction system which is adapted to reduce the concentration of nitrogen oxides contained in the exhaust gases emitted from the internal combustion engine. The system of the invention is characterized in that the exhaust gases are recirculated into the intake manifold only when the engine is driven under predetermined conditions represented by the engine speed and the level of the vacuum in the intake manifold of the engine.

It is well known that toxic nitrogen oxides are produced in large quantities when the vacuum in the intake manifold of the engine is decreased and the combustion temperature in the engine increased. To prevent the thus produced nitrogen oxides from being admitted to the open air, it has heretofore been proposed and put into practice to have the once emitted exhaust gases recirculated into the intake manifold and mixed with an inert gas to lower the combustion temperature so that the objectionable reaction which would otherwise take place between nitrogen and oxygen is precluded.

Continuous recirculation of the exhaust gases without respect of the operating conditions of the engine, as has thus far been the practice, results in unstable engine operation, decreased engine output and contamination within the engine and, as such, is considered unsuitable for practical purposes.

The problem of air-pollution resulting from the emission of toxic nitrogen oxides from automotive engines is a matter of great concern especially in urban areas of today and it is desired to reduce to a minimum the amount of nitrogen oxides emitted when the motor vehicle is running on city-roads. Extensive investigations conducted by the inventors have revealed that the nitrogen oxides emitted in such quantities as to cause a serious air-pollution problem in urban areas are produced mostly when the motor vehicle is accelerating or climbing a hill, as is discussed in more detail below.

The invention resides in the recognition that the drawbacks which result from the continuous recirculation of the exhaust gases can be effectively eliminated by selectively recirculating the exhaust gases only when the engine is driven under predetermined conditions in which the motor vehicle accelerates or climbs up a hill as frequently experienced in driving in urban areas.

Such conditions of the engine providing the acceleration or hill-climbing of the motor vehicle are represented, as preferable according to the invention, by two particular factors—the revolution speed of the engine and the vacuum in the intake manifold of the engine.

The present invention provides an induction system in an internal combustion engine for a motor vehicle, comprising: a recirculation passage communicating at one end with an exhaust manifold of said engine and at the other end with an intake manifold of said engine; an exhaust recirculation control valve disposed intermediate the ends of said recirculation passage and including a solenoid device for controlling communication between said exhaust and intake manifolds; first means responsive to vacuum in the intake manifold; and second means responsive to the revolution speed of the engine; said first and second means energizing said solenoid device only when said intake manifold vacuum is below a predetermined level and concurrently the engine is driven at a revolution speed within a predetermined range to provide communication between said exhaust and intake manifolds, whereby exhaust gases emitted from said exhaust manifold are recirculated into said intake manifold.

In the drawings:

Fig. 1 is a graphical representation of a typical example of the relationships between the vehicle speed of a motor vehicle running on city-roads and the concentration of nitrogen oxides in the emitted exhaust gases when the system according to the invention is used and not used;

Fig. 2 is a sectional view showing a preferred embodiment of the induction system of the invention as combined with a usual automotive engine;

Fig. 3 is a section on line I—I of Fig. 2;

Fig. 4 is similar to Fig. 2 but shows a modification of the system shown in Figs. 2 and 3;

Fig. 5 is also similar to Fig. 2 but shows partially another modification of the system shown in Figs. 2 and 3; and

Fig. 6 is a graphical representation of a region of the conditions in which the engine exhaust gases are to be recirculated by means of any of the systems illustrated in Figs. 2 to 5.

According to investigations conducted by the inventors on an automotive engine of usual construction, it has been discovered that the concentration of nitrogen oxides in the engine exhaust gases increases abruptly during acceleration and hill-climbing of the motor vehicle as indicated by the dotted curves *a′—b′* and *c′—d′* which correspond to the vehicle speed indicated by the lines *a—b* and *c—d*, respectively, in Fig. 1. In view of the fact that frequent decelerations, stops and accelerations occur and steep hills are encountered in city driving, it will be conductive to the reduction of air pollutants to lower the concentration of nitrogen oxides during the acceleration and hill-climbing of the vehicle, viz., when the vehicle is driven under the conditions represented by the lines *a—b* and *c—d* in Fig. 1.

In order to accomplish this purpose, the invention proposes to have the ranges *a—b* and *c—d* of the driving conditions of the motor vehicle represented by the revolution speed of the engine and the vacuum level in the intake manifold of the engine. In other words, the induction system of this invention is constructed in such a manner that the engine exhaust gases are recirculated into the intake manifold of the engine when, and only when, the engine is driven at a speed within a predetermined range and simultaneously the intake manifold vacuum is lower than a predetermined level.

A preferred embodiment of such a system is illustrated in Figs. 2 and 3.

Referring to Fig. 2, the system is used in combination with a conventional automotive internal combustion engine which is generally designated by numeral 1. The engine 1 has, as customary, an intake manifold 3 and exhaust manifold 2, and is combined with a carburettor 4 which is not shown in Fig. 2 for simplicity of illustration. The carburettor 4 is, however, mounted on the intake manifold 3 by a mounting flange 5. The carburettor 4 has, also as customary, a throttle valve 6 which is mounted on a rotary shaft 7, as shown in Fig. 3.

The induction system comprises an exhaust recirculation control valve 10, which is actually a solenoid valve device, mounted intermediate the ends of a recirculation passage comprised by an exhaust recirculation conduit 12 and an exhaust recirculation nozzle 13. The valve 10 has a casing 11 which communicates on one side with the exhaust manifold 2 through an exhaust recirculation conduit 12 and at one end with the intake manifold 3 through an exhaust recirculation nozzle 13. Alternatively the passage 13 may open into the carburettor 4 downstream of the throttle valve 6.

The valve 10 has provided in its casing 11 a valve head 14 which is positioned relative to a valve seat 15 formed integrally with the casing 11 in such a manner that the nozzle 13 is isolated from the conduit 12 when the valve head 14 is seated on the valve seat 15. The valve head 14 is integral with a hollow cylinder 16, which is axially movably mounted in the casing 11. A compression spring 17 is accommodated within this hollow cylinder 16 and urges the valve head 14 toward the valve seat 15. The valve head 14 is operated by a solenoid coil 18 which is connected with a power source 19.

The control valve 10 thus constructed is controlled by two switches connected in series with the solenoid coil 18 of the assembly 10—a vacuum switch 20 and an engine speed switch 21.

The vacuum switch 20 is controlled by a diaphragm device 22, which detects the vacuum in the intake manifold 3. The diaphragm device 22 has a vacuum chamber 23 and an atmospheric chamber 24 which are separated by a diaphragm member 25. The vacuum chamber 23 communicates with the intake manifold 3 through a vacuum conduit 26, while the atmospheric chamber 24 is vented to the atmosphere. The diaphragm member 23 is connected with the vacuum switch 20 through a connecting rod 27 extending through the atmospheric chamber 24. In the vacuum chamber 25 is mounted a compression spring 28 which urges the diaphragm member 25 toward the atmospheric chamber 24. Thus, when the intake manifold vacuum is at an elevated level, the diaphragm member 25 is pulled toward the vacuum chamber 23 against the action of the spring 28 thereby to keep the switch 20 open. When, in contrast, the intake manifold vacuum drops below a predetermined level, say, −350 mm of Hg, then the force exerted by

the spring 28 on the diaphragm member 27 exceeds the force acting on the diaphragm member 27 due to the pressure difference on opposite sides, and the diaphragm member 25 is moved toward the atmospheric chamber 24 to close the switch 20.

The engine speed switch 21, on the other hand, is controlled by a solenoid device 29 having a solenoid coil 30 and movable core 31. The core 31 is connected with the switch 21 through a connecting rod 32 and positioned to normally keep the switch 21 open and to close the switch when the solenoid coil 30 is energized. The solenoid coil 30 is connected to and energized by the output terminal of a pulse counter 33, the input terminal of which is connected to an ignition distributor 8 of the engine. The pulse counter 33 excites the solenoid coil 30 when it detects pulses at a rate proportional to an engine speed within a predetermined range so that the switch 21 is closed only when the engine is driven at a speed within a predetermined range, for example, from 1,500 to 3,200 rpm.

If preferred, a filter 34 may be provided in the exhaust recirculation conduit 12, whereby carbon particles contained in the exhaust gases are removed before they are introduced into the control valve 10. Thus, exhaust gases cleared of carbon particles will be recirculated into the intake manifold 3.

Also if preferred, a metering orifice 13*a* may be provided in the nozzle 13 to control the flow of exhaust gases to be drawn into the intake manifold.

When, in operation, the engine is driven under conditions in which the amount of nitrogen oxides emitted therefrom is allowable from the practical standpoint as during deceleration or normal cruising, then the revolution speed of the engine and/or the level of the vacuum in the intake manifold are outside the ranges within which the vacuum switch 20 and/or engine speed switch 21 are open. In this condition, the solenoid coil 18 of the solenoid device 10 is kept de-energized so that the valve head 14 remains seated by the action of the spring 17, isolating the conduit 12 from the nozzle 13. Thus exhaust gases in the exhaust manifold 2 are prevented from recirculating into the intake manifold 3.

When, on the other hand, the engine power output increases to such an extent as to produce nitrogen oxides in quantities to cause a serious pollution problem as represented by the dotted curve a'—b' or c'—d' in Fig. 1, then the intake manifold vacuum drops below the aforesaid predetermined level, for example, −350 mm of Hg and the engine speed falls within the aforesaid predetermined range, for example, anywhere between 1,500 and 3,200 rpm. In this condition, the force exerted by the spring 28 on the diaphragm member 27 exceeds the force acting on the diaphragm member 27 due to the pressure difference on opposite sides and the diaphragm member 25 moves into a position in which the switch 20 is closed. The solenoid coil 30 is consequently energized and the core 31 protruded to close the switch 21. The two switches 20 and 21 being now closed, the solenoid coil 18 of the solenoid valve device 10 becomes energized to cause the valve head 14 to be unseated from the valve seat 15 against the action of the spring 17, thereby permitting the exhaust gases to recirculate from the exhaust manifold 2 into the intake manifold 3 through the conduit 12 and the nozzle 13. The combustion temperature in the engine is lowered and the concentration of nitrogen oxides emitted to the open air is reduced from the levels represented by the dotted curves a'—b' and c'—d' to the solid curve a'—b'—c'—d' in Fig. 1.

The exhaust recirculation control valve which has been shown as a solenoid valve device 10 may be constructed otherwise inasmuch as the intent of recirculating the exhaust gases only when the engine is driven at predetermined speeds and the intake manifold vacuum is lowered below a predetermined level, one of such modifications being illustrated in Fig. 4.

The modified embodiment of the system according to the invention is essentially similar to that shown in Figs. 2 and 3 and, as such, like numerals are assigned to corresponding parts.

As shown, the exhaust recirculation control valve is constructed as a combination of a spool valve device 40 and a solenoid valve device 41 to control the former.

The spool valve device 40 has a casing 42 communicating on one side with the exhaust manifold 2 through a conduit 43 and on the same side with the intake manifold 3 through a nozzle 44. The conduit 43 is shown to open into the casing 42 at an inlet port 43*a* and the passage 44 to lead from the casing at an outlet port 44*a*. A metering orifice 45 may be provided in the nozzle 44 to control the flow of exhaust gases through the nozzle 44.

The casing 42 has accommodated therein a spool valve 46 having a land 47. A compression spring 48 is mounted in a chamber 49 formed between the end walls of the casing and the land 47 in such a manner that the spool valve 46 is urged toward a position in which the inlet port 43*a* is closed by the land 47, as shown.

The casing 42 further communicates with a casing 50 of the solenoid device 41 through a conduit 51. This casing 50 in the solenoid valve device 41 communicates at one end with the intake manifold 3 through the conduit 52 and on one side with the atmosphere, or with an air cleaner if preferred,

through a conduit 53. A core or valve member 54 is axially movably mounted in the casing 50 to act as a valve member and a compression spring 55 is mounted around the core or valve member 54 in a manner to urge the core or valve member 54 toward a position in which the conduit 52 is closed and the conduit 53 opened. In this condition, the casing 50 is prevented from communicating with the intake manifold 3 and is internally maintained at atmospheric pressure.

The valve member 54 is operated by a solenoid coil 56 which is connected in series with a power source 19, a vacuum switch 20 and an engine speed switch 21, similarly to the system illustrated in Fig. 2.

The switches 20 and 21 are controlled by a diaphragm device 22 and solenoid device 29, respectively, which are entirely similar in construction and function to the diaphragm device 22 and solenoid device 29 in Fig. 2 so that the discussion previously given applied thereto.

During deceleration or normal cruising of the motor vehicle when the amount of nitrogen oxides emitted from the engine is too low to cause a serious air-pollution problem, the solenoid valve device 41 remains de-energized because the solenoid coil 56 thereof is kept de-energized with the switches 20 and/or 21 open.

When, on the other hand, the engine output increases and nitrogen oxides are produced from the engine in quantities that cannot be neglected from the practical standpoint as indicated by the dotted curves a'—b' and c'—d' in Fig. 1, then the intake manifold vacuum decreases to below a predetermined level and the force exerted by the spring 28 on the diaphragm member 25 exceeds the force acting on the opposite direction on the diaphragm member 25 due to the pressure difference on opposite sides of the diaphragm member 25 and concurrently the engine is driven at a speed within a predetermined range to cause the solenoid device 29 to be energized. The switches 20 and 21 are now closed and the solenoid coil 56 of the solenoid valve device 41 energized. The valve member 54 is moved against the action of the spring 55 to a position to open the conduit 52 and close the conduit 53. The intake manifold vacuum that is now at a lowered level is communicated to the chamber 49 formed by the end walls of the casing 42 and the land 47 of the spool valve 46.

The pressure difference on opposite ends of the spool valve 46 causes the spool valve 46 to move against the force of the spring 48 (which is selected to yield to a vacuum at or below said predetermined level) to a position in which the land 47 opens the inlet port 43a. The conduit 43 is permitted to communicate with the nozzle 44 to enable exhaust gases to recirculate from the exhaust manifold 2 into the intake manifold 3.

As an alternative to the spool valve device 40 used in the above-described embodiment, a diaphragm valve device may be combined with the solenoid valve device 41 to constitute an exhaust recirculation control valve in the system according to the invention, an example being shown in Fig. 5.

In Fig. 5, only the diaphragm valve device which is generally denoted by 60 and the solenoid valve device which is similar to the counterpart in Fig. 4 and is numbered accordingly are illustrated, because the remaining essential elements are the same as used in the system in Fig. 4.

Referring to Fig. 5, the diaphragm valve device 60 has a vacuum chamber 61 defined by a diaphragm member 62 and the structural wall of the device 60, as shown. The vacuum chamber 61 communicates with the casing 50 of the solenoid valve device 41 through a conduit 51. A valve head 63 is connected with the diaphragm member 62 on the side of the diaphragm member remote from the vacuum chamber 61. A compression spring 64 is mounted in the vacuum chamber 61 in a manner to urge the diaphragm member 62 and accordingly the valve head 63 away from the vacuum chamber 61. The valve head 63 in this protruded position projects into a port 65 between an exhaust recirculation conduit 43 and the nozzle 44 thereby to isolate the conduit 43 and the nozzle from each other.

Now, as the engine power output increases and the switches 20 and 21 are closed, then the solenoid valve device 41 becomes energized to permit the intake manifold vacuum to be communicated to the vacuum chamber 61. The compression spring 64 is selected so as to yield at a vacuum below the predetermined level so that the diaphragm member 62 and accordingly the valve head 63 are moved toward the vacuum chamber 61 and away from the port 65. The valve head 63 thus retracted, the conduit 43 communicates with the nozzle 44 thereby to enable exhaust gases from the exhaust manifold to flow the intake manifold, similarly in function to the previously described embodiments.

The range in which the engine exhaust gases are recirculated into the intake manifold is shown in Fig. 6, wherein it is assumed, by way of example, that the exhaust gases are recirculated when the engine is driven at a speed ranging from 1,500 to 3,200 rpm and the intake manifold vacuum is lower than −350 mm of Hg. The recirculation range is indicated by the hatched area.

WHAT WE CLAIM IS:—

1. An induction system in an internal combustion engine for a motor vehicle, compris-

ing: a recirculation passage communicating at one end with an exhaust manifold of said engine and at the other end with an intake manifold of said engine; an exhaust recirculation control valve disposed intermediate the ends of said recirculation passage and including a solenoid device for controlling communication between said exhaust and intake manifolds; first means responsive to vacuum in the intake manifold; and second means responsive to the revolution speed of the engine; said first and second means energizing said solenoid device only when said intake manifold vacuum is below a predetermined level and concurrently the engine is driven at a revolution speed within a predetermined range to provide communication between said exhaust and intake manifolds, whereby exhaust gases emitted from said exhaust manifold are recirculated into said intake manifold.

2. A system as claimed in claim 1, wherein said predetermined level of the intake manifold vacuum and said predetermined range of the engine speed correspond to the vehicle engine operating conditions during acceleration and hill-climbing.

3. A system as claimed in claim 1 or 2, wherein said predetermined level is −350 mm of Hg and said predetermined range is 1,500 to 3,200 r.p.m.

4. A system as claimed in claim 1, 2 or 3, wherein said first means includes a vacuum switch and a diaphragm device comprising a vacuum chamber communicating with the intake manifold, an atmospheric chamber vented to the atmosphere and a diaphragm member separating said vacuum and atmospheric chambers from each other, said diaphragm member being urged towards a position in which the vacuum switch is open, but being moved to a position in which the vacuum switch is closed when the intake manifold vacuum is below said predetermined value; and said second means includes an engine speed switch and a solenoid device having a solenoid coil and movable core, said movable core being connected with said engine speed switch and normally held in a position to open the same, and a pulse counter which energizes said solenoid coil only when the engine is driven within said predetermined range whereby said movable core moves into a position to close said engine speed switch, said exhaust recirculation passage being opened by the control valve to provide communication between the inlet and exhaust manifolds only when said vacuum and engine speed switches are closed concurrently.

5. A system as claimed in claim 4, wherein said exhaust recirculation passage includes an exhaust recirculation conduit communicating with the exhaust manifold and an exhaust recirculation nozzle communicating with the inlet manifold, wherein the control valve assembly includes a valve head which is positioned relative to a valve seat formed in a casing with which said nozzle and said conduit communicate, a compression spring accommodated in said casing to urge said valve head against said valve seat to isolate said conduit from said nozzle, and wherein the solenoid device includes a movable core connected with said valve head, and a solenoid coil associated with the last-mentioned movable core and connected with a power source and with said vacuum and engine speed switches, said last-mentioned movable core being moved away from said valve seat against the action of the last-mentioned spring to cause said valve head to be unseated only when the last-mentioned solenoid coil is energized by said vacuum and engine speed switches being closed concurrently, whereby said conduit communicates with said nozzle.

6. A system as claimed in claim 4, wherein said control valve includes a spool valve device, said spool valve device including a casing communicating with the exhaust manifold through an exhaust recirculation conduit and with the intake manifold through an exhaust recirculation nozzle, the exhaust recirculation passageway including said conduit and said nozzle, a spool valve axially movably mounted in said casing and having a land, and a compression spring mounted in said casing to urge said spool valve toward a position in which said land isolates said conduit from said nozzle, said solenoid valve device including a solenoid valve casing communicating with said casing of the spool valve device, said solenoid valve casing further communicating with the intake manifold through a vacuum conduit and with the atmosphere, a core axially movably mounted in said solenoid valve casing and acting at the same time as a valve member, said core being normally urged into a position to isolate said vacuum conduit from said casing of said spool valve device by spring action, and a solenoid coil associated with said core and connected with a power source and with said vacuum and engine speed switches, said core being moved to a position to permit said vacuum conduit to communicate with said casing of said spool valve device to cause said spool valve to be moved against the action of said spring in said spool valve device to a position in which said land places said exhaust recirculation conduit in communication with said nozzle only when said solenoid coil of said solenoid valve device is energized by said vacuum and engine speed switches being closed concurrently.

7. A system as claimed in claim 4, wherein said control valve includes a diaphragm valve device, said diaphragm valve device including a vacuum chamber, a diaphragm member forming part of the structure of said

vacuum chamber, a port communicating with the exhaust manifold through an exhaust recirculation conduit and with the intake manifold through an exhaust recirculation nozzle, a valve head connected with said diaphragm member and directed toward said port, and a compression spring mounted in said vacuum chamber to urge said diaphragm member toward a position in which said valve head closes said port, said solenoid valve device including a solenoid valve casing communicating with said casing of the diaphragm valve device, said solenoid valve casing further communicating on one side with the intake manifold through a vacuum conduit and on the other with the atmosphere, a core axially movably mounted in said solenoid valve casing and acting at the same time as a valve member, said core being normally forced into a position to isolate said vacuum conduit from said casing of said diaphragm valve device by spring action, and a solenoid coil associated with said core and connected with a power source and with said vacuum and engine speed switches, said core being moved to a position to permit said vacuum conduit to communicate with said casing of said diaphragm valve device to cause said diaphragm member to be moved against the action of said spring in said diaphragm valve device to a position in which said valve head opens said port whereby said exhaust recirculation conduit is permitted to communicate with said nozzle only when said solenoid coil of said solenoid valve device is energized by said vacuum and engine speed switches being closed concurrently.

8. A system as claimed in any preceding claim, wherein said exhaust gases are recirculated into the intake manifold through a filter to remove carbon particles contained therein.

9. A system as claimed in any preceding claim, wherein said exhaust gases are recirculated into the intake manifold through a metering orifice.

10. An induction system in an internal combustion engine for a motor vehicle, substantially as described herein with reference to and as illustrated in Figs. 2 and 3, Fig. 4 or Fig. 5 of the accompanying drawings.

MARKS & CLERK.

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Fig. 1

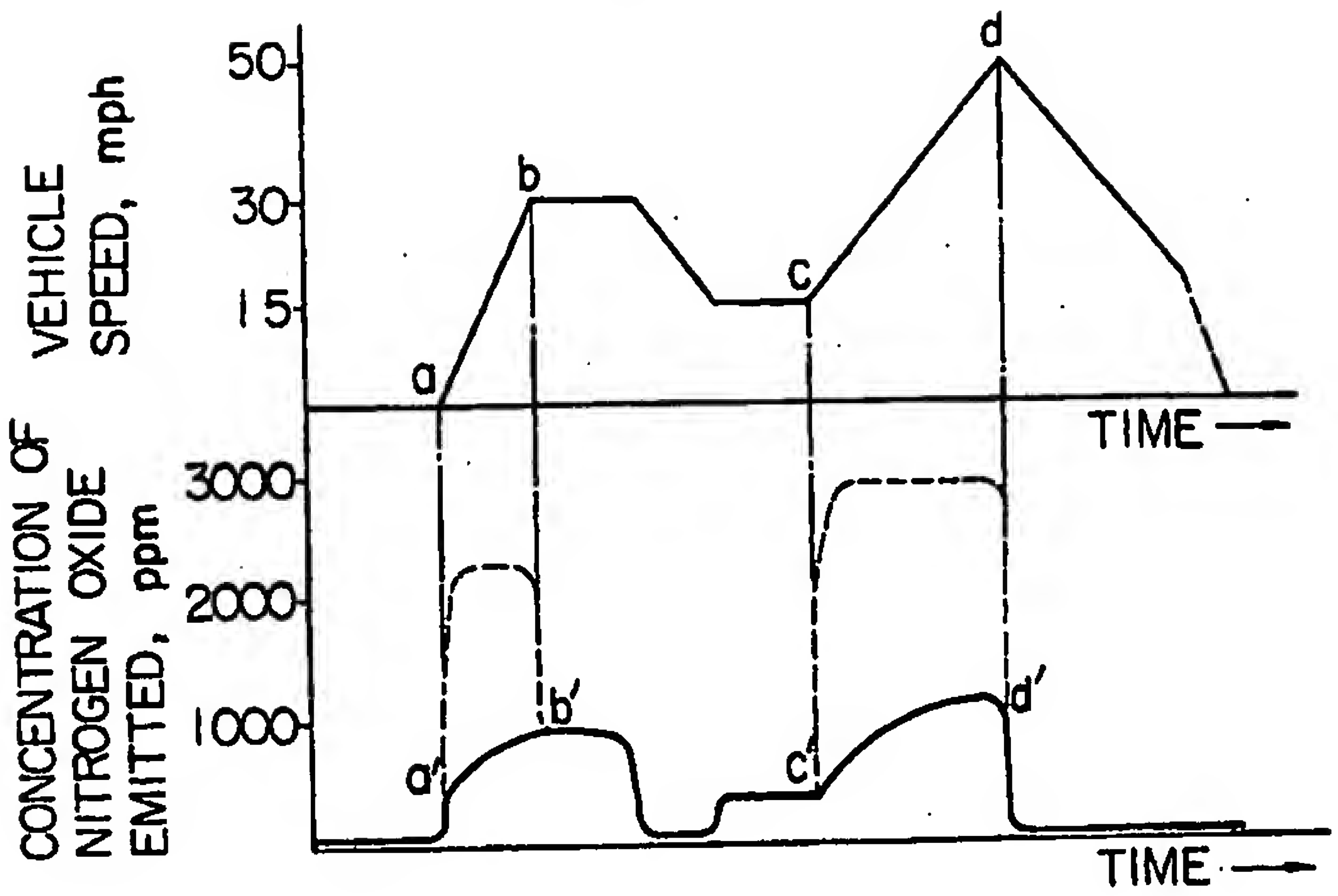
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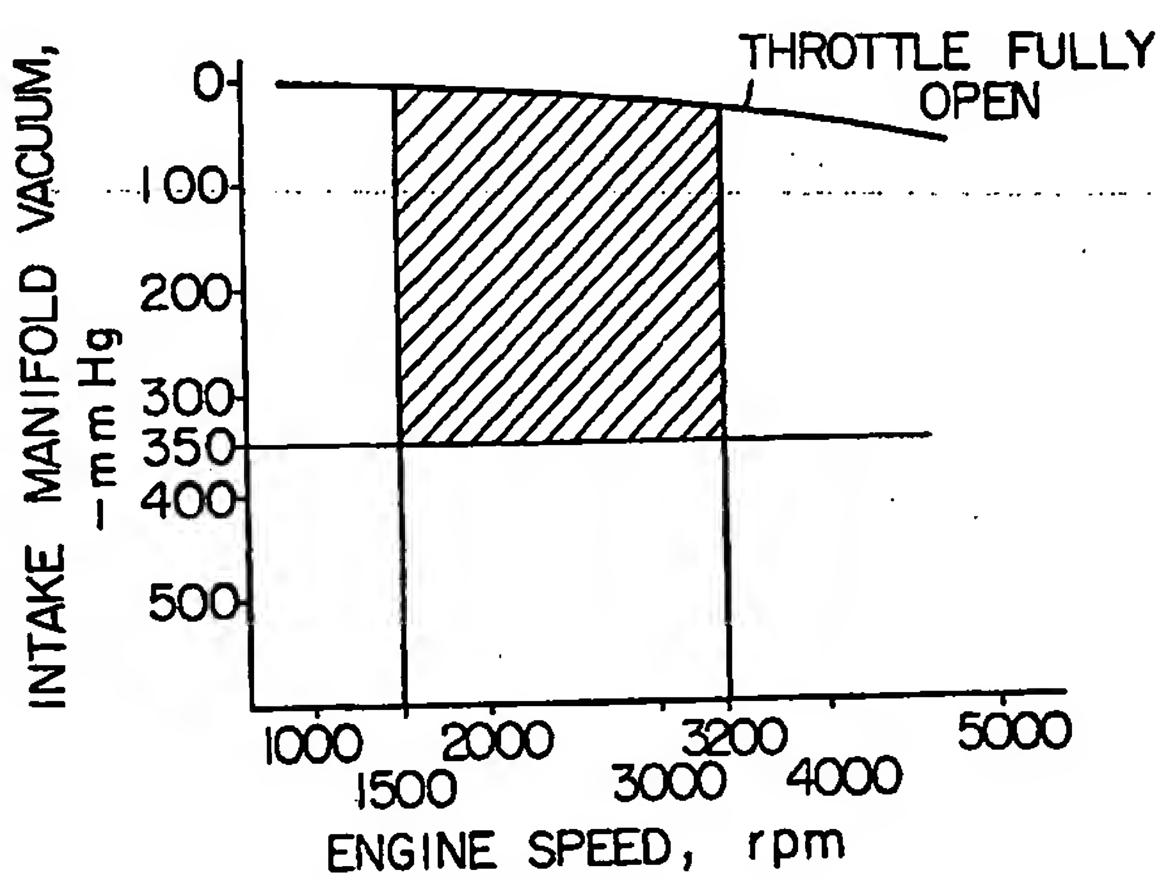
Fig. 6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ENGINE SPEED, rpm

1270516 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig. 2

Fig. 3

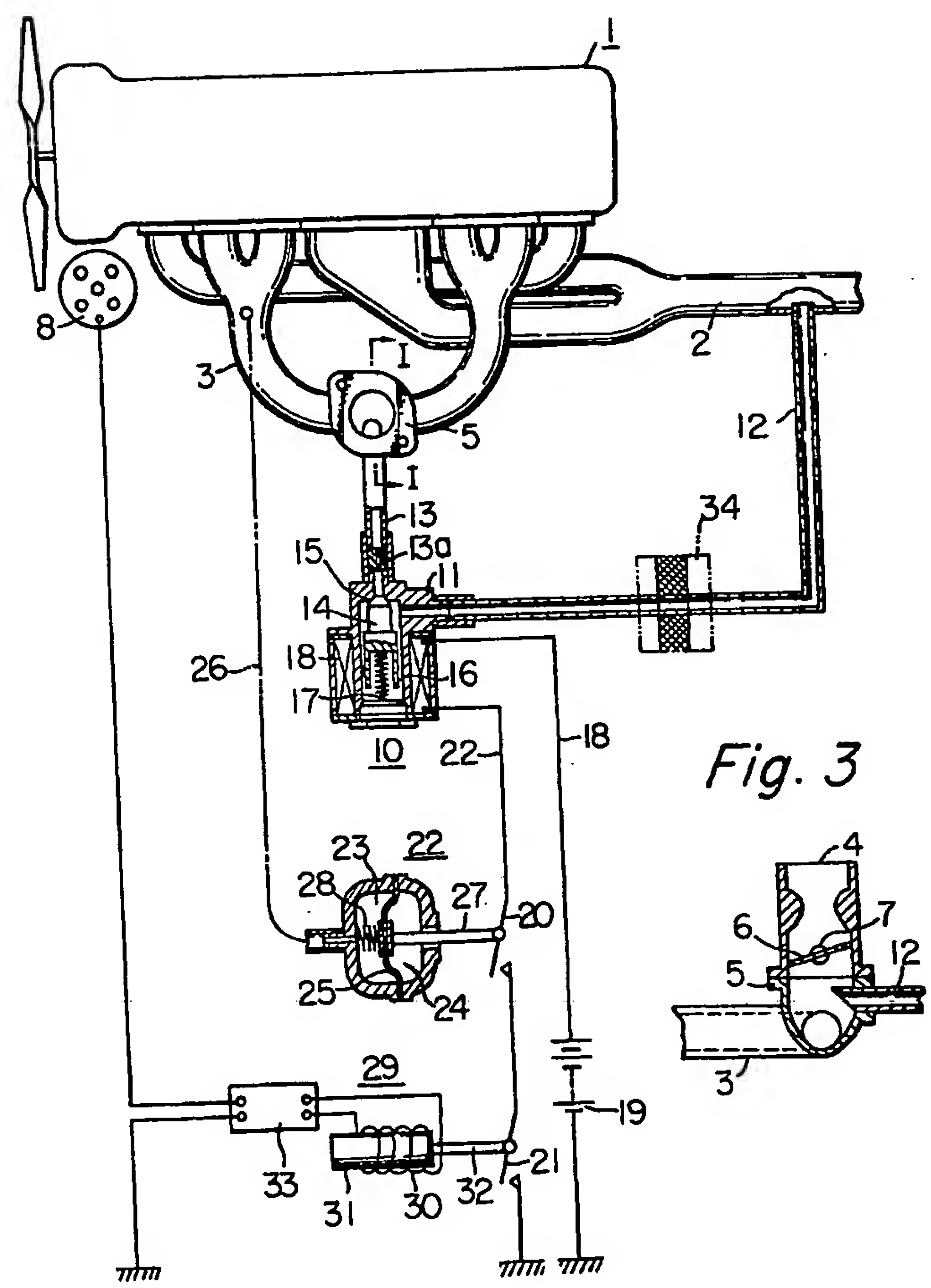

Fig. 4

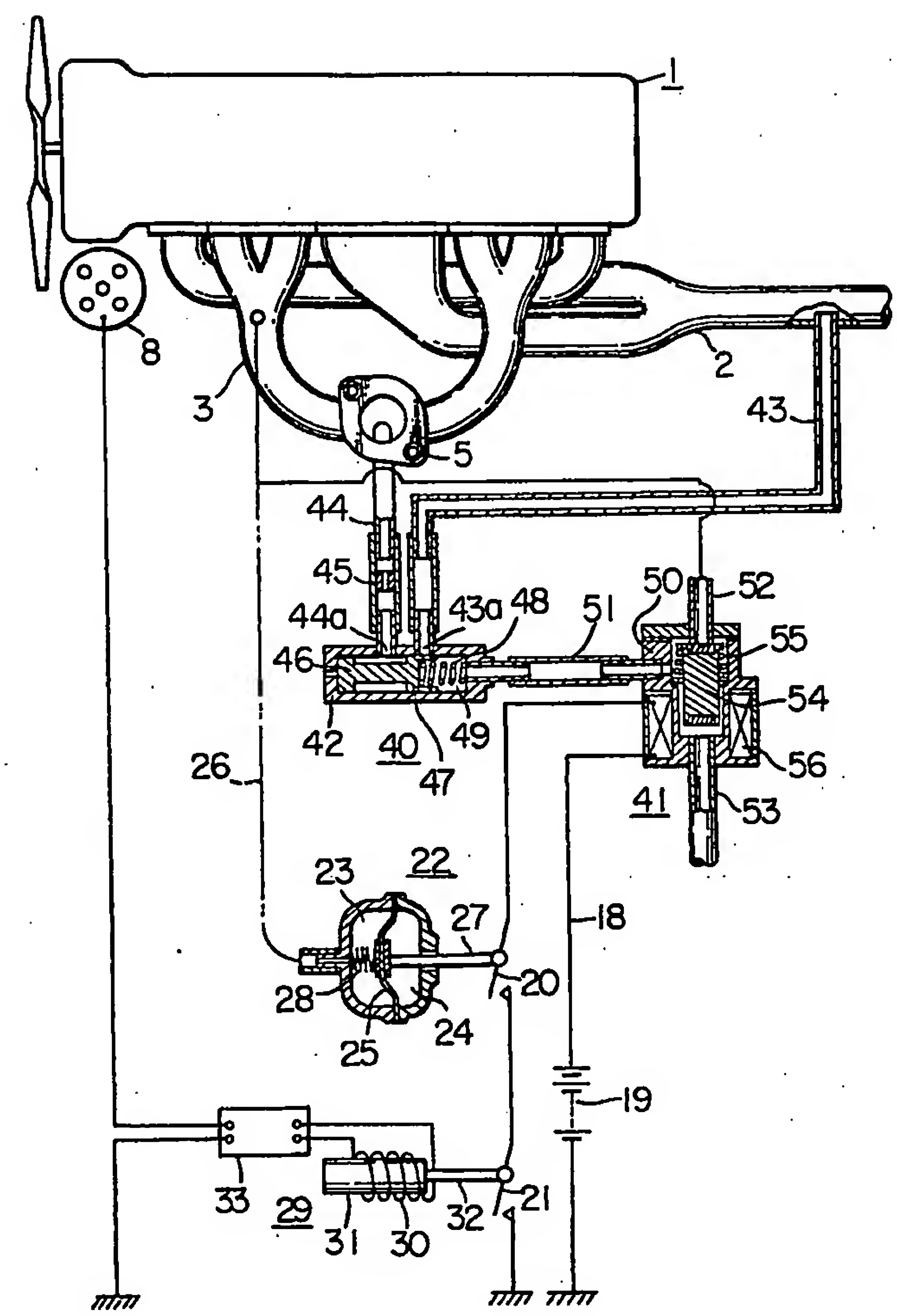
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Fig. 5